DTMF Remote Telephone Switch

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In spite of alternatives based around the Internet, SMS and e-mail, the good old DTMF remote switch still has its place, and, thanks to the use of a modern microcontroller, is simple and economical.

Today a telephone connection is available anywhere and at any time, with forms of communication other than speech having been available for some time. Alongside SMS and WAP there is the simpler established technology, known as 'Dual Tone Multi Frequency', or DTMF for short, which we use here in order to control a circuit. Telephone service providers have used this dialling system in the analogue telephone network to replace pulse dialling, which dates from days of mechanical uniselectors. Once a telephone connection is in place, a transmitted tone can be used in order to trigger a desired action. This technique, well known from its use in remotely accessing answering machines or conversing with service providers, here allows us to use the keypad to control three circuits once a call has been set up.

Circuit Operation

The remote control switch is connected in parallel with the telephone apparatus: this does not restrict the use of the telephone in any way. After a selectable number of rings the circuit lifts the receiver and sends an acknowledgement tone to signal to the caller that a four-digit code number is to be entered. Ten seconds are allowed for the entry of each digit, and each digit is acknowledged by a tone. If the time limit is exceeded, an error sound is produced and the receiver replaced on-hook.

Once all four digits are received they are compared with stored code numbers. If the digits are not in agreement with any of the stored numbers, the error sound is again produced and the call is terminated. The circuit is then immediately ready for a new call.

Each of the three switching outputs is assigned two sequences of digits, one to switch the output stage on and the other to switch it off. If the same four-digit number is received a second time, the circuit does not change state. The states of the outputs are stored in EEPROM in the PIC and so are preserved in the case of a power failure. Programming the six sequences of digits and the selection of the number of rings is done using the telephone, which should is connected to the programming socket for this purpose. These digit sequences are also permanently stored in EEPROM in the PIC.

The full circuit of the remote telephone switch is shown in **Figure 1**. The PIC16F84 microcontroller (IC3) examines incoming signals on port B and controls the outputs over port A. Connection to the telephone network is via RJ45 connector K2. Socket K3 is connected in parallel with socket K2 and allows a telephone to be connected at the same time as the circuit. Since in practice the pinout of the connectors is rather less standardised than it is in theory, we have used jumpers here. A voltage-dependent resistor (varistor) is connected across these two sockets, which provides protection against voltages in excess of 130 V.

The DTMF signal to be processed (an AC signal with a DC offset) is brought in to the circuit via D1 to D4. Because of this diode bridge, the polarity of the signal is no longer relevant. The ring signal is an AC voltage, which passes through capacitor C1 to bridge rectifier D5 to D8. Since this voltage can be as high as 60 V, an optocoupler (IC1) is used before the input to the PIC. Capacitor C1 ensures that only the ring signal, and not the DC offset, reaches the optocoupler.

IC2 is a DTMF decoder type MT8870. It is connected to the telephone line via C3 and R10 and presents a hexadecimal value corresponding to the two tones at its outputs Q1 to Q4. These outputs are latched and so are only valid when the control output STD is high. Inputs RB6 and RB7 are used as two auxiliary inputs to control the PIC. Pushbutton switch S1 puts the PIC into programming mode, allowing the possible entries shown in **Table 1**. Jumper JP1 selects between a permanently enabled output or an output switched on for just five seconds. This function allows the operation of door openers with a single call, for example. Type CNY17 optocouplers are used at the switching outputs, which provide an isolated connection to the outside world on connectors K5 to K7. The optocouplers can switch voltages of up to 35 V at currents of up to 10 mA. They also prevent an earth potential from a controlled device from coming into contact with the remote control switch. Since this earth potential is also on the telephone line, this can lead to interference on the telephone connection if isolation is not used. Signal output to the telephone line is via two transistors. T3 produces a line current of approximately 20 mA, which corresponds to lifting the receiver. When T1 is driven by the PIC, it is switched on and off at a frequency of 325 Hz and adds an extra alternating current of 2 mA. This causes the caller to hear a tone. T2 fulfils the same function, creating a tone on the telephone connected to K1.

Two supply voltages are required for the remote telephone switch circuit. A DC or AC 12 V mains adaptor is connected to bridge rectifier B1 via K4. IC2 and IC3 are supplied with a regulated 5 V from a 7805 fixed voltage regulator. The unregulated voltage of approximately 12 V is required only for the telephone used in programming mode. The voltage appears across the contacts of K1 and a current flows through the telephone apparatus and R1 to ground. A DTMF signal also appears across R1, which is taken to the input of the MT8870 via C4 and R11.

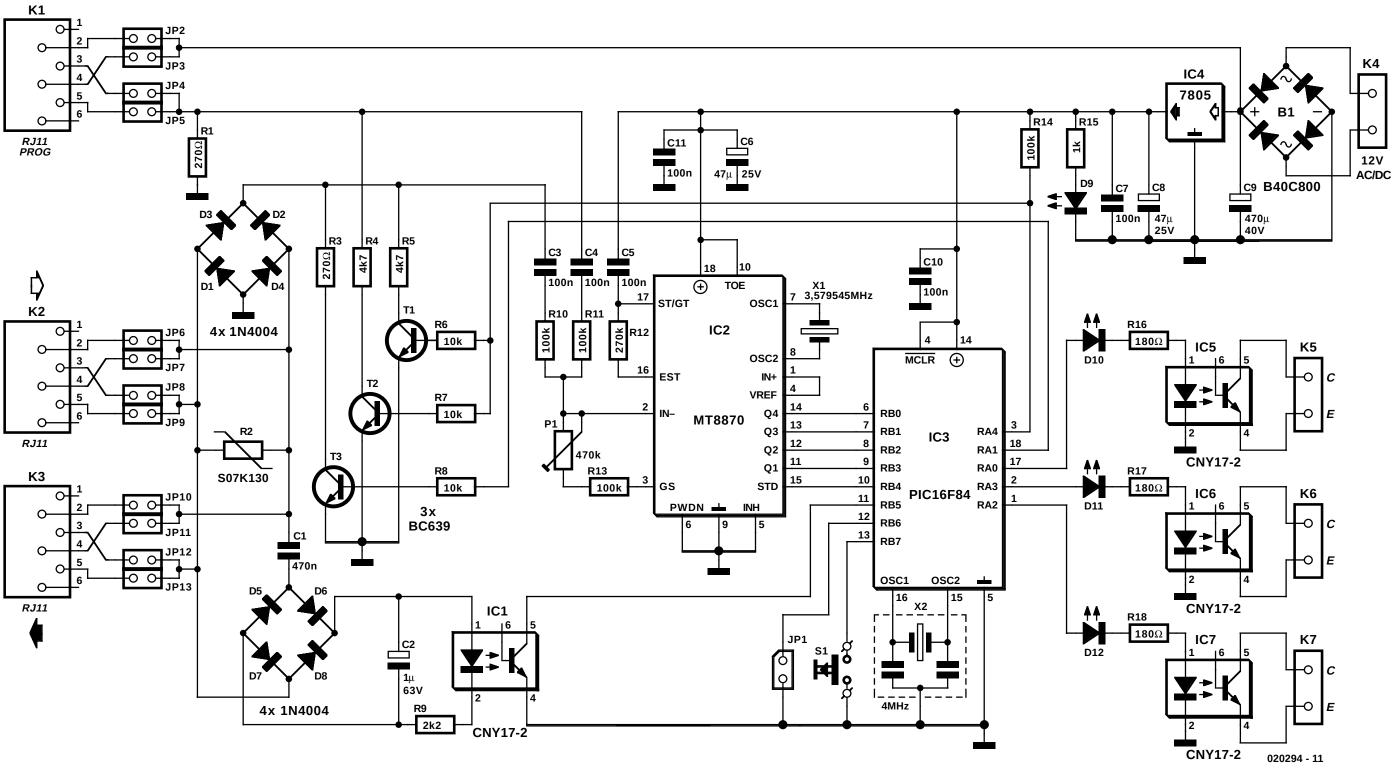

Figure 1. Circuit diagram of the telephone remote control.

The Software

The PIC is the central control component and monitors the state of the telephone line, reads hexadecimal values corresponding to DTMF tones, lifts the telephone receiver, transmits acknowledgement signals and switches the output stages. All these functions are implemented in the PIC assembler program **`020294.ASM`**. A simple illustration of the operation of this program is shown in the flowchart of **Figure 2**. First of all the inputs and outputs are initialised. All the port A connections are configured as outputs and all the port B connections as inputs. The internal pull-up resistors on port B are enabled. Next, the values stored in EEPROM corresponding to the six digit sequences and ring count are copied into RAM.

The main program now starts by reading the state of the programming button (S1) and the ring detector (IC1). If neither of the signals is active, they continue to be monitored in an infinite loop.

If the programming button is detected as being pressed the programming subroutine is entered. Here five digits are read in sequence, corresponding to the control of an output stage. The first digit specifies the function of the digit sequence, as well as its storage location in EEPROM. If a ring signal is detected the ring counter is decremented: when it reaches zero, the receiver is lifted (via RA1).

To confirm that a call has been picked up, two 400 ms signal tones at 325 Hz are emitted. In subroutine **`READDTMF`** the value corresponding to a DTMF signal is read when input RB4 goes high. This reading process is repeated four times and the digit sequence received is stored in registers **`NUMBERHI`** and **`NUMBERLO`**. Then the digit sequence that has just been read is compared with the stored values in six identical program segments (**`COM1ST,`** etc.). If no number matches, control passes to program segment **`WRONG`**, where six 325 Hz signal tones of 200 ms duration spaced at 100 ms intervals are emitted, and the receiver replaced on-hook.

If a match occurs with one of the six stored digit sequences the appropriate control action is carried out: the corresponding output stage (IC5 to IC7) is turned on or off. The first output is a special case. When it is turned on, the level at RB6 (i.e., jumper JP1) is checked. If it is low, IC5 is automatically turned off again after a five second delay. If, on the other hand, JP1 is open, the output turns on permanently. After each control action an 800 ms confirmation tone is emitted.

In the following program segment the state of the three output stages is stored in EEPROM at address 0Eh. Then the main program is begun again with a **`GOTO START`**. All tests, such as ring recognition, ring pause, DTMF recognition and DTMF pause time out after ten seconds if the corresponding event does not occur. After an error tone is emitted and the receiver is replaced on-hook (**`GOTO WRONG`**), and control returns to the start of the program.

Construction

Construction of the telephone remote control is easier than might appear from a first look at the layout

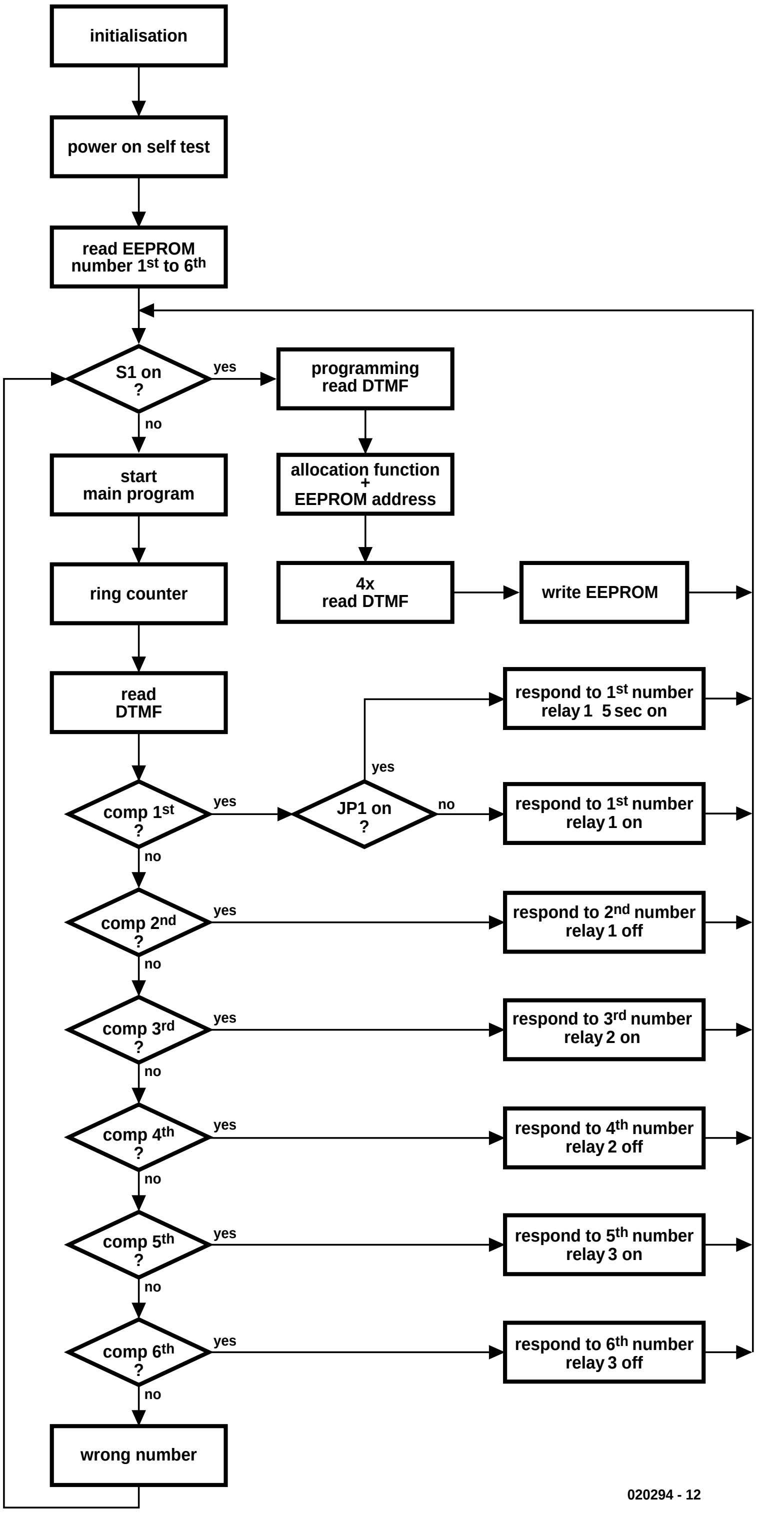
initialisation
power on self test
read EEPROM number 1st to 6th
S1 on ?
yes
no
programming read DTMF
start main program
allocation function + EEPROM address
ring counter
4x read DTMF
write EEPROM
read DTMF
respond to 1st number relay 1 5 sec on
yes
comp 1st ?
yes
JP1 on ?
no
respond to 1st number relay 1 on
no
comp 2nd ?
yes
respond to 2nd number relay 1 off
no
comp 3rd ?
yes
respond to 3rd number relay 2 on
no
comp 4th ?
yes
respond to 4th number relay 2 off
no
comp 5th ?
yes
respond to 5th number relay 3 on
no
comp 6th ?
yes
respond to 6th number relay 3 off
no
wrong number
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Figure 2. Software flowchart.

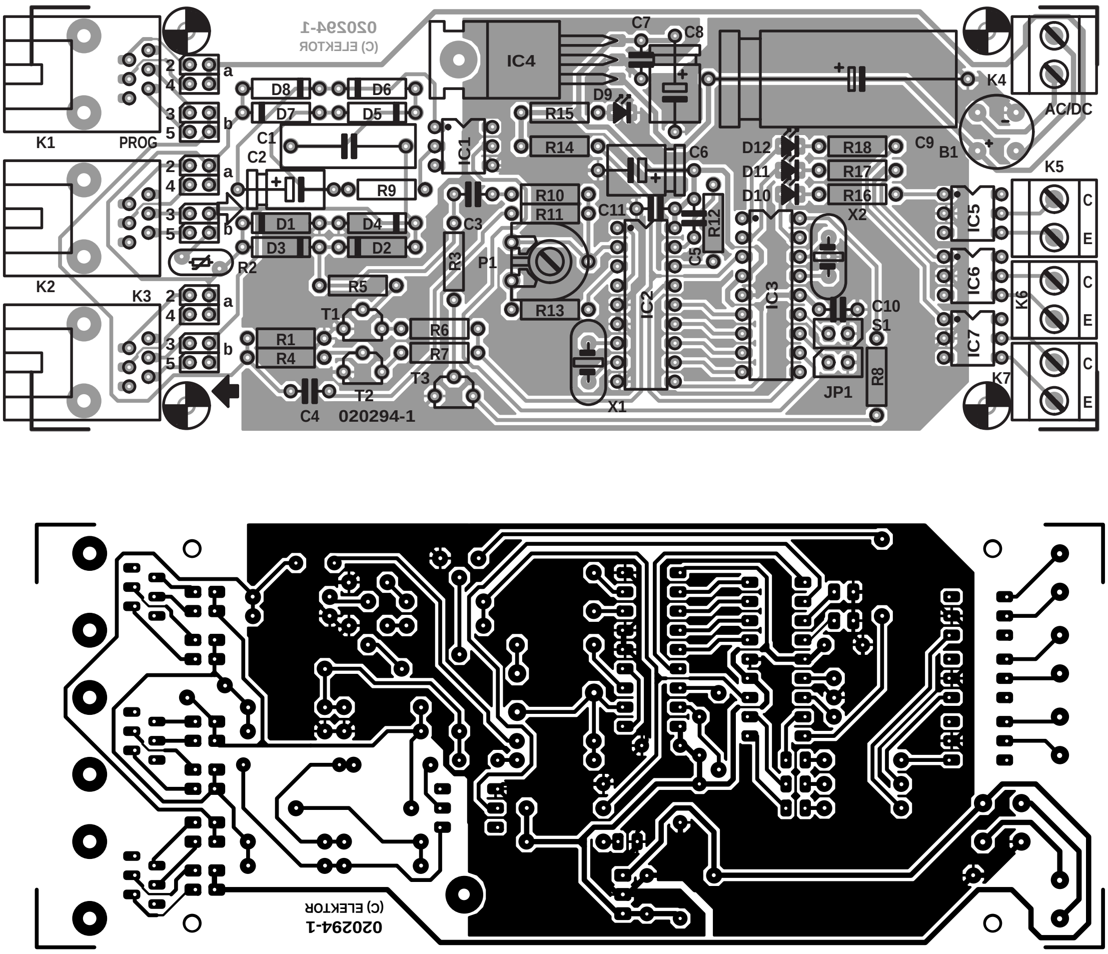

Figure 3. Layout and component mounting plan for the telephone remote control.

and component mounting plan in **Figure 3**. All the components are 'normal' leaded ones (no SMDs), the printed circuit board is single-sided but nevertheless is free of wire links. Sockets are recommended for the ICs. Be careful to observe correct polarity for the many diodes and electrolytic capacitors (and of course for the ICs).

The jumpers next to the telephone sockets may be inelegant, but are necessary. Unfortunately, with the RJ11 analogue telephone connector, there appears to be no effective international agreement on the pinout. In a few countries, telephones are connected across pins 2 and 5, in most, however, across pins 3 and 4. For this reason we have included the facility on the printed circuit board to accommodate either possibility: the correct connections can be selected using jumpers JP2 to JP13, or using wire links. No damage can be done in this way: either the circuit will work or it will not.

For a first test of the telephone remote control IC2 and IC3 should not be fitted in their sockets. Once the two supply voltages have been verified, the operation of the optocou-

COMPONENTS LIST

Resistors:
R1,R3 = 270Ω
R2 = S07K130 (130V varistor)
R4,R5 = 4kΩ7
R6,R7,R8 = 10kΩ
R9 = 2kΩ2
R10,R11,R13,R14 = 100kΩ
R12 = 270kΩ
R15 = 1kΩ
R16,R17,R18 = 180Ω
P1 = 470kΩ (500kΩ) preset

Capacitors:
C1 = 470nF 100V MKT, lead pitch 5mm
C2 = 1µF 63V axial
C3,C4,C5,C7,C10,C11 = 100nF, lead pitch 5mm
C6,C8 = 47µF 25V axial
C9 = 470µF 40V axial

Semiconductors:
B1 = B40C800, round case (80V piv, 0.8A)
D1-D8 = 1N4004
D9 = LED, low current, red, 3mm
D10,D11,D12 = LED, green, 3mm
IC1,IC5,IC6,IC7 = CNY17-3
IC2 = MT8870DE
IC3 = PIC16F84A-20/P, programmed, order code **020294-41**
IC4 = 7805
T1,T2,T3 = BC639

Miscellaneous:
JP1 = 2-way pinheader with jumper
K1,K2,K3 = RJ11, PCB mount
K4,K5,K6,K7 = 2-way PCB termibal block, lead pitch 5mm
S1 = pushbutton, 1 make contact, chassis mount
X1 = 3.579545MHz quartz crystal
X2 = 4MHz 3-pin ceramic resonator
Optional: 24-way SIL pinheader with 6 jumpers
PCB, order code **020294-1**
Disk, project software, order code **020294-11** or Free Download

Table 1 Programming mode

Entry					Function
1	2	3	4	5	
0	X	0-10	X	X*	Ring count
1	X	X	X	X	K5 on
2	X	X	X	X	K5 off
3	X	X	X	X	K6 on
4	X	X	X	X	K6 off
5	X	X	X	X	K7 on
6	X	X	X	X	K7 off

X = any DTMF key
* = 0, * and # = 10

plers can be checked. To do this, apply a high level to pins 1, 2 and 17 of the (empty) IC3 socket. The corresponding LED should light and the output transistor of the optocoupler should turn on. The output transistor of IC1 should also conduct when a ringing voltage is present on socket K2. Since K2 and K3 are wired in parallel, it is unimportant which is used as an input and which as an output.

The tone signal output can be tested by applying a high level to RA1 and RA4: the result should be a crackling sound in the telephone earpiece. When testing T1 and T3 in this way, the circuit must be connected to the telephone network, since this function depends on the voltage it provides.

Once all tests are successfully completed (and all power sources are disconnected from the circuit) IC2 and IC3 can be fitted.

Now, when power is applied, the 'line sound' (325 Hz), along with the programming tone (2 kHz and 2.5 kHz) should be audible at K1 and K2. The next step is to set the gain of the MT8870. This is done by first lifting the receiver and pressing any number key. A high level at STD on IC2 (pin 15) indicates correct recognition of the DTMF signal. The adjustment is carried out using potentiometer P1. Either K1 or K2 may equally well be used.

Number entry

Now the six sequences of digits can be entered, along with the ring count. First S1 must be pressed: this is acknowledged by a tone in the earpiece of the telephone connected to K1. If the program has recently detected activity on the telephone line (a ring signal or a DTMF tone), the timeout period must be allowed to expire before programming mode can be entered.

Now the first digit can be entered (indicating the function according to **Table 1**), followed by a four-digit sequence. All entries are acknowledged by a signal tone (see **Table 2**). Four digits must be entered even when the ring count is being set, although only the second digit is significant, indicating, from 1 to 9, the number of rings. If a different key is pressed (0, * or #), the ring counter will be preloaded with 10. It is not possible to read the stored values out of the memory. If they are forgotten, the only solution is to reprogram them afresh.

When the PIC is first used after its program code has been loaded into it, all the output stages are turned on, the ring counter is set at 10 and all digit sequences are set to 'CCCC' (in DTMF code). These values are changed when the unit is first configured using DTMF tones.

The circuit can be tested by simply calling oneself and watching the effect of the call and the received signals on the receiving telephone and on the remote control. There is also the possibility of carrying out this test without incurring the cost of a telephone call. Remove optocoupler IC1, connect socket K2 to the telephone network and lift the receiver on the telephone connected to K3. The collector and emitter connections of IC1 should be bridged for about one second to simulate a ring: this should be done a suitable number of times, according to the ring count setting.

The call acknowledgement tone should be heard in the earpiece, and a four-digit sequence should be entered. The signal tones shown in the table should be heard, overlaid by the tones from the connected telephone. During this process the tones entered can cause an outgoing call to be set up, and so use of the other connector is recommended for programming. If the circuit is not to be used for some time, the power supply should be disconnected, but the telephone connection need not be unplugged. Note that this means that if there is a power cut, the telephone connection will not be blocked.

(020294-1)

Table 2

Tones produced when receiving digit sequences and during programming

Action	Tone sequence
Incoming call received	C, C, W, W, C, C
Entry acknowledgement	Digits 1 to 3: C; digit 4: confirmation or error signal
Output on/off confirmation	C, C, C, C
Error: operation aborted	C, W, C, W, C, W, C, W, C, W, C
Programming mode entry	B, B, A, A, B, B, A, A, B, B
Programming mode entry acknowledgement	Digit 1: B or error signal; digits 2 to 4: A; digit 5: confirmation
Programming confirmation	A, B, A, B, A, B, A
Error: programming mode aborted	B, W, B, W, B, W, B, W, B, W, B

Key: A = 2500 Hz / 100 ms; B = 2000 Hz / 100 ms;
C = 325 Hz / 200 ms; W = 100 ms pause

Note:
the circuit described in this article is not BABT approved for connection to the public switched telephone network. Aproval has not been applied for.

Free Downloads

Microcontroller software (hex and source code).
File number: **020294-11.zip**
PCB layout in PDF format.
File number: **020294-1.zip**
www.elektor-electronics.co.uk/dl/dl.htm, select month of publication.